



# The Carbon Cycle Pursuit Game

## Teacher's Guide

- [www.atd.ucar.edu/apol/biocomplexity](http://www.atd.ucar.edu/apol/biocomplexity)
- [www.eo.ucar.edu](http://www.eo.ucar.edu)

### Subject Focus:

Earth Science  
Biology  
Chemistry

### Materials & Preparations

#### Time:

**Preparation:** 30 minutes to make one game, although the process can be greatly expedited by involving students

**Introduction:** 10 minutes

**Playing time:** 30 minutes

#### Materials:

- game board
- game instructions (can be affixed to back side of game board)
- 7 dice, one color-coded to correspond to a specific carbon reservoir
- 7 color-coded sets of ten question cards corresponding to a specific carbon reservoir
- 1 game piece token/marker per team

#### Teacher Materials:

See Assembly Instructions that follow

### National Science Content Standards Addressed:

Standards C, D, and F

### Learning Objectives:

- Learn the biological carbon cycle as each team moves as carbon through the atmosphere, oceans, biosphere, and lithosphere
- Correctly identify and use the terms carbon source, sink, and reservoir
- Learn about human's role today in impacting the carbon cycle
- Understand that the carbon cycle is a dynamic system that plays a significant role in Earth's atmospheric composition
- Understand that changes in Earth's atmospheric composition impact climate and life on Earth

### Objective of Game:

Small groups of 2-3 students work together to correctly answer questions about the carbon cycle and advance through all seven carbon reservoirs on the game board before their opposing team.

### Procedure:

1. Assemble game pieces as instructed on the Assembly page at least one day prior to play. For a class of 30 students, five games should be constructed. It takes approximately 30 minutes to assemble one game setup.

**Game Day Directions:** Have competing teams read and discuss the Carbon Cycle Pursuit Directions page together before beginning play. Ask the class as a whole if there are any questions pertaining to how to play the game. After all questions are answered, begin play.

### Extensions and Assessment:

Ask teams to develop new sets of questions for the game. Assign them a particular reservoir or have them determine a set number of questions for each. Make sure that students list their sources for their questions' content. Some excellent sources can be found in the appendix to *Carbon, Climate and Laser Technology*.

The Carbon Cycle Pursuit game is intended as a review or to expand student knowledge following class content on the carbon cycle and/or climate change. Teachers can create their own question cards on the blank question card template provided to emphasize specific learning objectives. Students' ease in correctly answering the question cards will be indicative of their understanding of the carbon cycle and its connection to Earth's climate.

# Carbon Cycle Pursuit · Game Directions



**LEARNING OBJECTIVE:** To increase students' knowledge of the carbon cycle and humans' impact on it.

**GAME OBJECTIVE:** To be the first team to cycle through all carbon reservoirs on the game board. To win, one must correctly answer a carbon card question while in each reservoir, then roll the appropriate dice to advance to another location within the carbon cycle.

## MATERIALS:

- Game board
- 7 sets of question cards
- Minute glass for keeping time (optional)
- 7 carbon cycle dice
- Token for each team

## HOW TO PLAY THE GAME:

1. Have students form competing teams, each with two or three players.
2. Distribute items listed under "Materials" to each pair of competing teams.
3. Set out the game board, place each color-coded die near its matching carbon reservoir, and place the seven stacks of carbon question cards along side the game board, image-side up.
4. Present the game's objective and rules to the class as a whole, or have competing teams review them independently.

## RULES OF THE GAME:

1. The team with a member possessing a birthdate closest to the day's date goes first. (It does not matter if the birth date has recently past or is upcoming.) The team going first is referred to as Team A; the team going second, Team B.
2. Each team puts their marker in the *Fossil Fuel* reservoir to begin. Each carbon reservoir is image- and color-coded (e.g. "orange" with a traffic image for the *Fossil Fuel* reservoir; "green" with a plant image for the *Vegetation* reservoir).
3. Team B pulls the first question card from the *Fossil Fuel* stack and reads the carbon question to Team A, whose players have one minute to discuss and decide on their answer. (The answer is specified on the card.)
4. If Team A players do not answer the question correctly, their turn is over and the question card goes to the bottom of the stack. However, if they do answer correctly, they receive the question card and a roll of the *Fossil Fuel* reservoir die to attempt to advance.
5. If Team A rolls the die and it lands showing another reservoir, Team A may advance their token to it, and their turn ends. If they roll the die and it lands on the reservoir they are currently in, they must remain there, and their turn ends. They will have an opportunity to advance after answering another carbon card question correctly on their next turn.
6. Team B now repeats the same process.
7. After a team's players correctly answer a carbon card question in the same reservoir three times but fail to advance to a new reservoir, or if all questions in the reservoir have been exhausted, they may move their token to another carbon reservoir shown on their die.
8. To win, a team must be first to successfully cycle through all seven reservoirs on the game board and receive a carbon question card from each by correctly answering its question.

# Carbon Cycle Pursuit

## Game Assembly Teacher Instructions



### Materials needed for Game Assemblance:

- Copy of Carbon Cycle Pursuit Directions
- Copy of game board, preferably in color
- A color copy of each reservoir die (7 total)
- 7 Manila folders or 7 pages of firm paper stock (20 lb. weight)
- Two-sided Question Cards printed and laminated (8.5"x11"pages)
- Container to hold game contents
- Envelope or rubber band for question cards
- Two game piece tokens, one for each team, preferably representing a component of the carbon cycle
- Use of a laminator machine, printer, and copier
- Clear tape or stapler

### Advanced Preparation:

For a class of 30 students, with three students per team, you will need to prepare five Carbon Cycle Pursuit games. To make the process easier, solicit student assistance. Instructions for making one game follow:

- Step 1: Print the following on a color printer: game board, 2-sided question cards (7 double-sided pages), and the 7 color-coded reservoir dice (*materials follow on attached pages*)
- Step 2: On the backside of the game board page, copy the game directions.
- Step 3: Laminate the game board and directions page as well as the question card pages.
- Step 4: Cut out the question cards and organize them by reservoir. Each of the 7 reservoirs will have a set of 10 game card questions that are color-coded to match the reservoir and the reservoir die.
- Step 5: Cut out the 7 die along each die's outline and staple or glue each to one side of a manila folder or heavier paper stock. Cut out each die with its new backing, and fold into a cube along dotted lines. Secure fold with tape to maintain each die's cube shape. (*See illustrations that follow.*)
- Step 6: Add two markers/game pieces of your choosing -- one for each team -- to complete the advanced preparation of the Carbon Cycle Pursuit game. You may wish to choose markers that reflect some component of the carbon cycle (e.g. a leaf, pumas rock) or have each team do so for homework prior to playing the game.

## Carbon Pursuit Game Board



## Carbon Pursuit Game Dice (7)



## Carbon Pursuit Questions





# Carbon Cycle Pursuit

**Atmosphere**



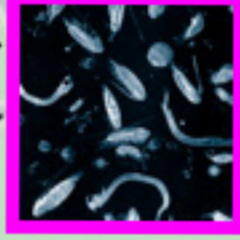
**Surface Ocean**



**Deep Ocean**



**Marine Biota**



**Vegetation**



**Soil**



**Fossil Fuels**



Diffusion

Diffusion

Photosynthesis

Respiration

Land Use

Burning of Fossil  
Fuels

Decomposition

Circulation

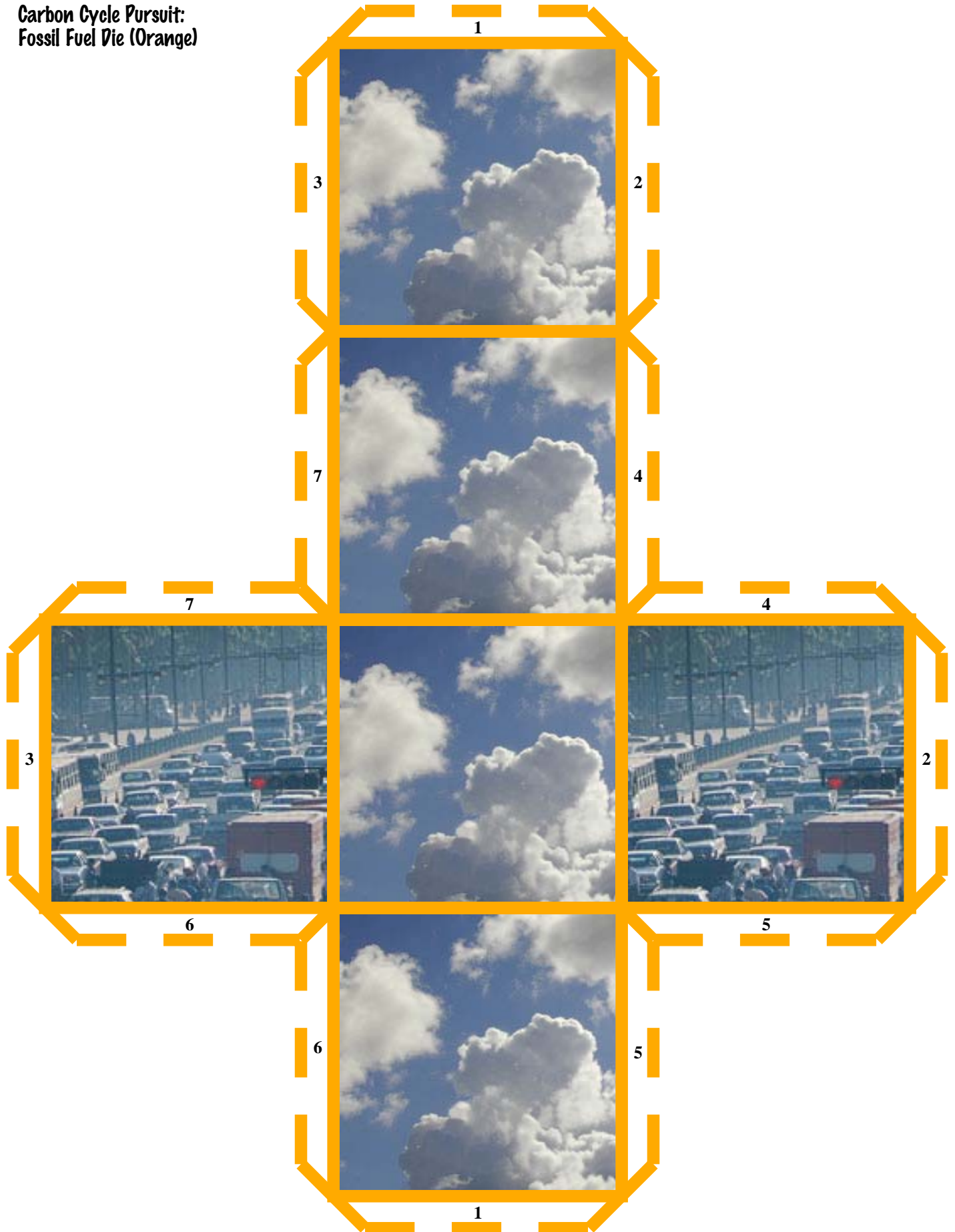
Circulation

Decomposition

Decomposition

**Carbon Cycle Pursuit**  
[www.atd.ucar.edu/apol/biocomplexity](http://www.atd.ucar.edu/apol/biocomplexity)

**Carbon Cycle Pursuit:  
Fossil Fuel Die (Orange)**



**Carbon Cycle Pursuit**  
**Atmosphäre Die (Sky Blue)**

1



3

2

7

4



7

4



3



6

5



6

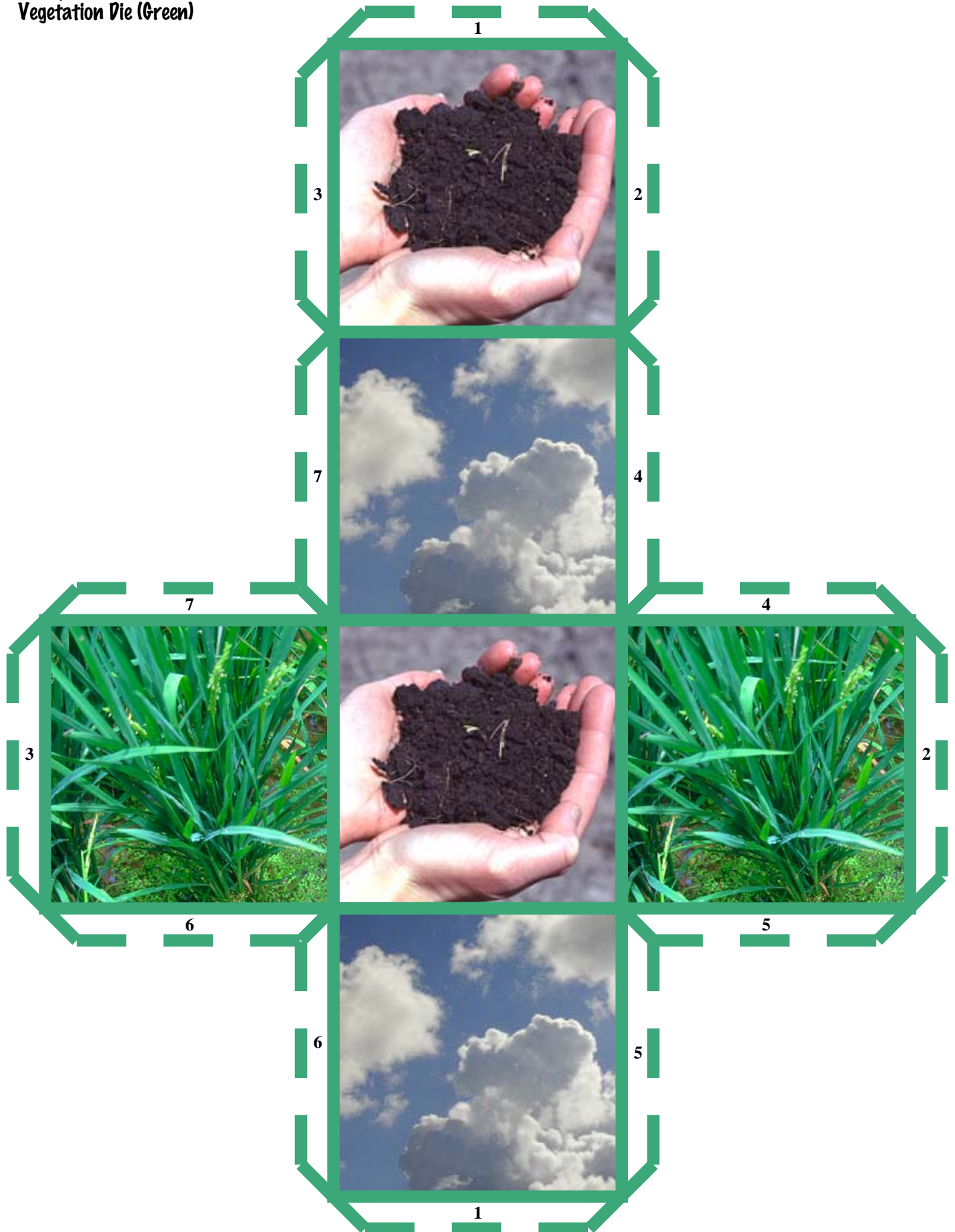
5

1

2

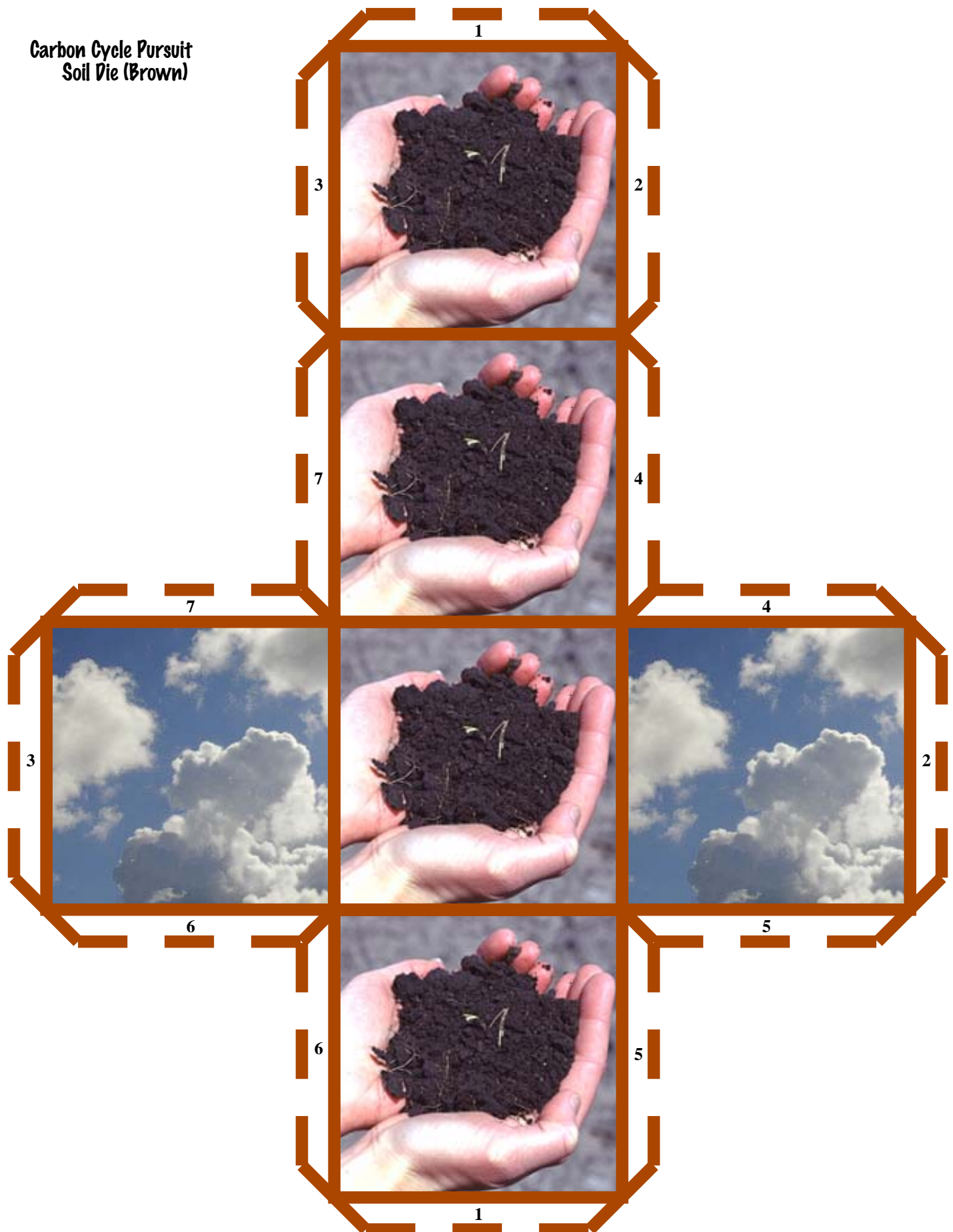


Carbon Cycle Pursuit  
Vegetation Die (Green)





Carbon Cycle Pursuit  
Soil Die (Brown)



Carbon Cycle Pursuit  
Surface Ocean Die  
(Ocean Blue

1



3

2

7

4



7

4



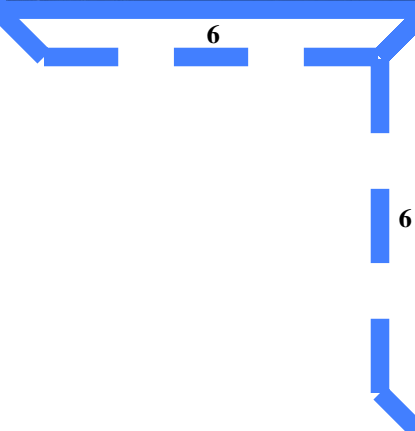
3



2

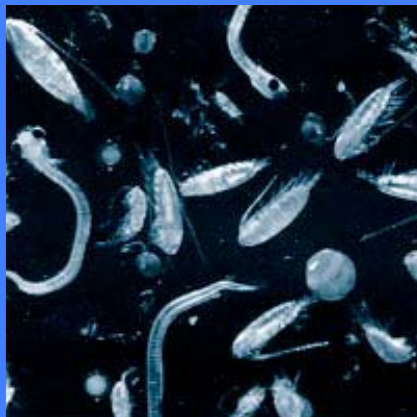
6

5



6

5



1

Carbon Cycle Pursuit  
Marine Biota Die (Pink)

1



3

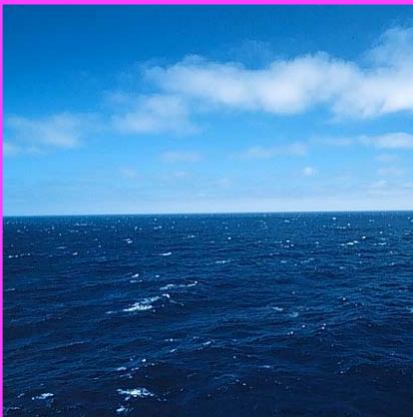
2

7



4

7



3

6



4

2



5

6

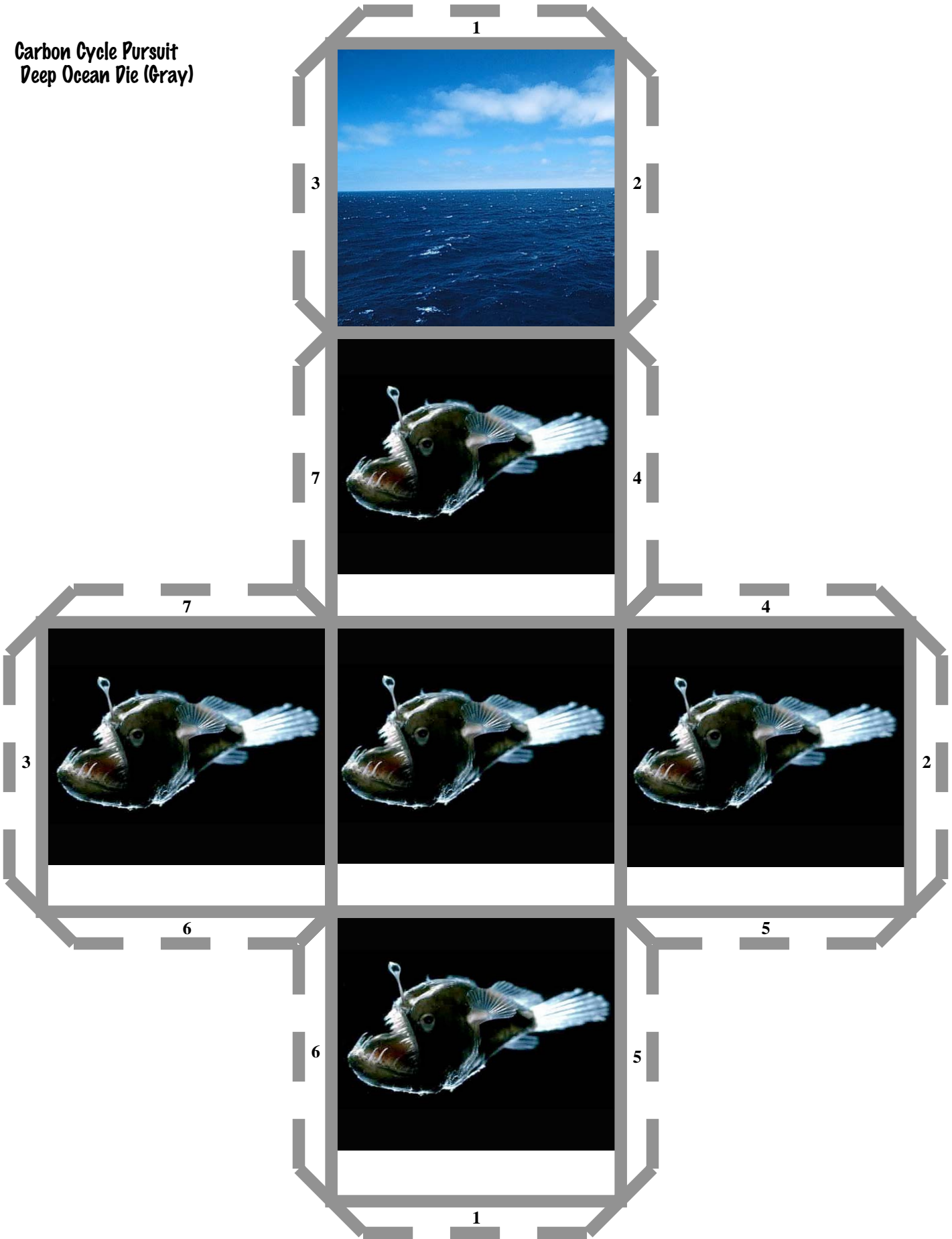


5

1



Carbon Cycle Pursuit  
Deep Ocean Die (Gray)



## FOSSIL FUELS

*Approximately how many Megatons of Carbon do humans produce by burning fossils fuels each year?*  
(1 Megaton = one million tons)

- a. 5
- b. 50
- c. 500
- d. 5,000

**d**

*How does the US get the majority of its energy?*

- a. Petroleum
- b. Natural Gas
- c. Coal
- d. Oil

**a**

*What percent of our countries electricity comes from the burning of coal?*

- a. 10%
- b. 20%
- c. 40%
- d. 60%

**d**

*How many pounds of carbon is each person in the US responsible for producing per year?*

- a. 46
- b. 460
- c. 4600
- d. 46000

**c**

*How many pounds of carbon is each person in Japan responsible for producing per year?*

- a. 180
- b. 1800
- c. 18000
- d. 180000

**b**

*How many trees would each American have to plant to make up for how much CO<sub>2</sub> we release into the atmosphere each year?*

- a. 8
- b. 80
- c. 800
- d. 8,000

**c**

*Which state uses the most oil to produce electricity?*

- a. California
- b. New York
- c. Colorado
- d. Florida

**d**

*Coal power plants produce approximately \_\_\_\_ of CO<sub>2</sub> emissions from electric utilities in the US.*

- a. 35%
- b. 50%
- c. 75%
- d. 90%

**d**

*True or False: Ccar engines exist that do not produce CO<sub>2</sub> as a byproduct.*

**True**

*True or False: Increased CO<sub>2</sub> levels in the atmosphere will be detrimental to ones health.*

**True**

## FOSSIL FUELS

## FOSSIL FUELS



## FOSSIL FUELS



## ATMOSPHERE

What percent of the atmosphere is carbon dioxide?

- a. 0.04%
- b. 0.4%
- c. 4%
- d. 40%

**a**

What percent of the atmosphere was carbon dioxide before the start of the industrial revolution?

- a. 0.0028%
- b. 0.028%
- c. 0.28%
- d. 2.8%

**b**

True or False:  $\text{CO}_2$  is a very reactive molecule in the atmosphere.

**False**

How much of an increase of  $\text{CO}_2$  in the atmosphere have we seen since the industrial revolution?

- a. 5% increase
- b. 15% increase
- c. 30% increase
- d. 50% increase

**c**

The radiative forcing due to  $\text{CO}_2$  is at present slightly larger than \_\_\_\_\_ of the total greenhouse gas forcing.

- a. 50%
- b. 26%
- c. 12%
- d. 4%

**a.**

Geochemical measurements made on ancient ocean sediments suggest that atmospheric  $\text{CO}_2$  levels over the past \_\_\_\_\_ years were never as high as they are today.

- a. 100,000
- b. 500,000
- c. 5,000,000
- d. 20,000,000

**d**

The average annual increase of  $\text{CO}_2$  since 1958 has been \_\_\_\_\_ ppm (parts per million per year).

- a. 0.5
- b. 1.0
- c. 1.5
- d. 2.0

**c**

The increase of  $\text{CO}_2$  in the atmosphere for years 2002 and 2003 were \_\_\_\_\_ ppm and \_\_\_\_\_ ppm, (parts per million) respectively.

- a. 0.5, 0.6
- b. 1.0, 1.1
- c. 1.7, 1.8
- d. 2.4, 2.3

**d**

$\text{CO}_2$  atmospheric concentrations increased by \_\_\_\_\_ ppm (parts per million) in 2004.

- a. 1.5
- b. 2.0
- c. 2.5
- d. 3.0

**a**

True or False: Release of a carbon dioxide molecule affects the atmosphere for a very long time.

**True**

## ATMOSPHERE

ATMOSPHERE



ATMOSPHERE

## VEGETATION

Which of the following releases CO<sub>2</sub> into the atmosphere?

- a. burning wood
- b. harvesting wood
- c. clearing of forest
- d. all of the above

**d**

True or False: Forests that grow after being cut down by logging companies serve as large carbon sinks. (Meaning they take up a lot of CO<sub>2</sub>)

**True**

Forest cover about \_\_\_ of the land surface of the earth.

- a. 1/2
- b. 1/3
- c. 1/4
- d. 1/6

**b**

True or False: Plants both absorb CO<sub>2</sub> from the atmosphere and release it, and therefore serve as both a source and a sink in the carbon cycle.

**True**

True or False: Worldwide, forested land is being cleared at a rate of about one football field per second.

**True**

The process by which the plants give off CO<sub>2</sub> is called

- a. regeneration
- b. regurgitation
- c. respiration
- d. relaxation

**c**

A carbon sink is

- a. something that stores carbon
- b. something that gives off carbon
- c. something that destroys carbon
- d. can be any of the above

**a**

A carbon source is

- a. something that stores carbon
- b. something that gives off carbon
- c. something that destroys carbon
- d. can be any of the above

**b**

Plants and forests serve as

- a. carbon sinks
- b. carbon sources
- c. both
- d. neither

**c**

True or False: If atmospheric CO<sub>2</sub> levels continue to increase, plants will take in more CO<sub>2</sub> and grow faster.

**True**

## VEGETATION



VEGETATION



VEGETATION

## SOIL

Which of the following take up  $\text{CO}_2$  from the atmosphere?

- a. soil
- b. ocean
- c. plants
- d. all of the above

**d**

True or False: When plants die and deteriorate into the soil, they release  $\text{CO}_2$ .

**True**

The soil serves as a

- a. carbon sink
- b. carbon source
- c. both
- d. neither

**b**

Detritus is

- a. small organisms living in the soil
- b. dead plants and animals deteriorating in the soil
- c. the scientific name for worms
- d. another name for soil

**b**

Soils store about \_\_\_\_ of the earth's total  $\text{CO}_2$ .

- a. 3%
- b. 13%
- c. 30%
- d. 63%

**a**

True or False: Soils emit more  $\text{CO}_2$  into the atmosphere than humans.

**True**

The erosion and weathering of rocks

- a. release  $\text{CO}_2$
- b. store  $\text{CO}_2$
- c. both
- d. neither

**a**

True or False: Carbon compounds in the soil react to form humus.

**True**

Currently the US farmlands are responsible for storing \_\_\_\_ metric tons of carbon.

- a. 2 million
- b. 20 million
- c. 100 million
- d. 200 million

**b**

If the US were to increase the carbon storage in its farmland tenfold over the next 40 years, this total uptake would account for \_\_\_\_ of the US yearly output in carbon.

- a. 12%
- b. 24%
- c. 48%
- d. 96%

**a**

## SOIL

SOIL



SOIL

## SURFACE WATER

True or False: *The ocean absorbs more CO<sub>2</sub> than land.*

**False**

True or False: *The surface ocean stores more carbon than soils.*

**False**

*The surface ocean absorbs approximately \_\_\_\_ GtC per year. (GtC = Gigatons of Carbon)*

- a. 20
- b. 50
- c. 90
- d. 140

**c**

True or False: *The ocean helps regulate the amount of CO<sub>2</sub> in the atmosphere.*

**True**

True or False: *As carbon dioxide enters the surface water, much of it reacts and only a small fraction of it remains in CO<sub>2</sub> form.*

**True**

*Much of DIC (Dissolved Inorganic Carbon) in the surface water is*

- a. transported to the poles by ocean currents
- b. sinks to the deep ocean
- c. absorbed by fish
- d. none of the above

**a**

True or False: *More carbon can dissolve in cold water than in warm water.*

**True**

*The \_\_\_\_\_ is the process by which large biologically formed particles sink into the deep ocean.*

- a. oceanic pump
- b. dissolution
- c. oceanic decay
- d. biological pump

**d**

*The mechanism by which skeletal structures of sea life transfer carbon to the deep ocean by sinking is called*

- a. the skeletal pump
- b. the carbonate pump
- c. the carcass pump
- d. the calcium pump

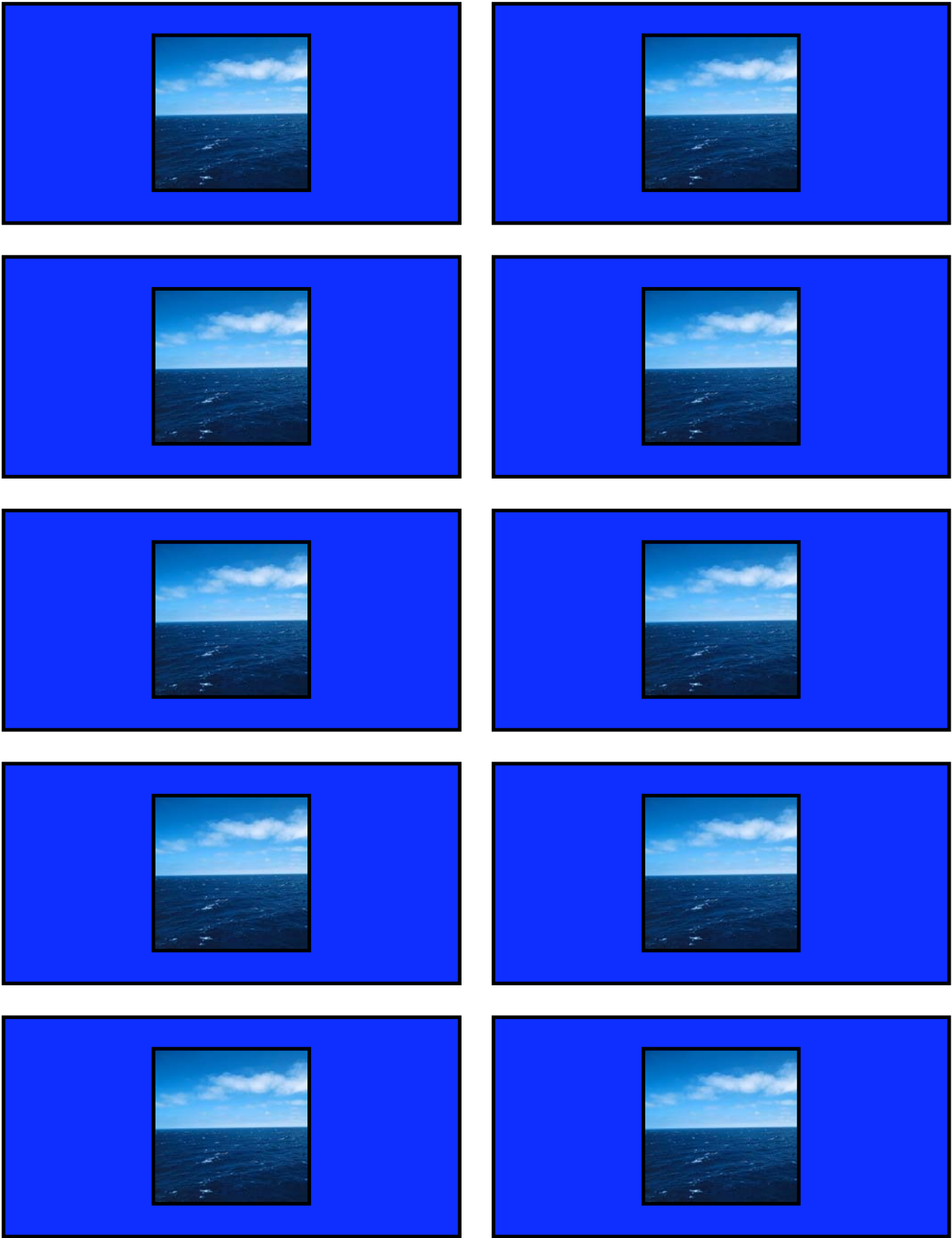
**b**

True or False: *The surface ocean only absorbs CO<sub>2</sub> from the atmosphere.*

**False**

## SURFACE WATER

SURFACE WATER



SURFACE WATER



## MARINE BIOTA

True or False: *Phytoplankton are a class of microorganisms that take in CO<sub>2</sub> in the ocean.*

**True**

*Phytoplankton is eaten by*

- a. zooplankton
- b. fish
- c. whales
- d. all of the above

**d**

*Microorganisms will die if*

- a. pH becomes too high or low
- b. carbon to nitrogen ratios are changed
- c. temperature significantly changes
- d. all of the above

**d**

*Marine Biota utilize \_\_\_\_ GtC annually. (Gigatons of carbon)*

- a. 5
- b. 20
- c. 50
- d. 80

**c**

True or False: *Shells in the ocean contain CO<sub>2</sub>.*

**False**

True or False: *Ocean life can survive without carbon.*

**False**

True or False: *When carbon levels get too high, they prevent sea animals from undergoing the chemical processes that form their shells (calcium carbonate).*

**True**

*Which animals will be hurt by increased CO<sub>2</sub> levels?*

- a. algae
- b. mollusk
- c. coral
- d. all of the above

**d**

True or False: *The marine biota reservoir is the only reservoir where its yearly fluxes are much larger than the size of the reservoir itself.*

**True**

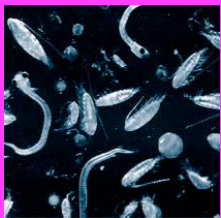
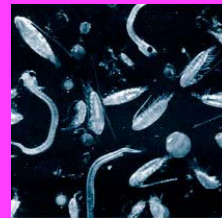
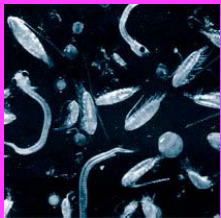
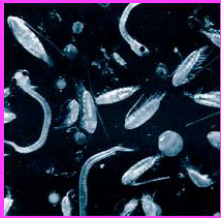
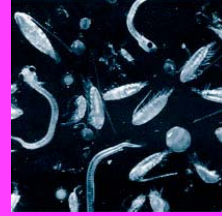
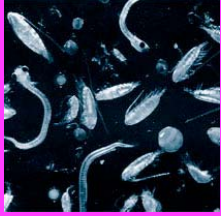
*The most dynamic reservoir in the carbon cycle is*

- a. plants
- b. soils
- c. ocean
- d. marine biota

**d**

## MARINE BIOTA

MARINE BIOTA



MARINE BIOTA

## DEEP OCEAN

Carbon dioxide that enters the Deep Ocean is removed from the carbon cycle for \_\_\_\_ of years.

- a. tens
- b. hundreds
- c. thousands
- d. millions

**b**

True or False: Once the CO<sub>2</sub> enters the deep ocean, we don't have to worry about it for at least 100 years.

**True**

True or False: Once the CO<sub>2</sub> enters the deep ocean, it will never circulate up again and cause CO<sub>2</sub> levels to rise in the atmosphere.

**False**

At the poles

- a. Cold dense water sinks to the ocean floor and fills the ocean basins
- b. Much of the CO<sub>2</sub> freezes and is trapped in the polar ice
- c. The CO<sub>2</sub> is released into the atmosphere
- d. none of the above

**a**

The mechanism by which the ocean circulates CO<sub>2</sub> from the surface water to the deep oceans near the poles is called the

- a. oceanic circulation
- b. dissolution
- c. oceanic transpiration
- d. solubility pump

**d**

True or False: When cold water from the deep ocean heats up, it releases CO<sub>2</sub> while rising to the surface.

**True**

The deep ocean accounts for more than \_\_\_\_ of the earth's carbon.

- a. 5%
- b. 16%
- c. 50%
- d. 65%

**d**

The deep ocean gets carbon from

- a. the surface ocean
- b. marine biota
- c. both
- d. neither

**c**

Where are we likely to see a carbon buildup first?

- a. at the poles
- b. at the equator
- c. everywhere
- d. its random

**a**

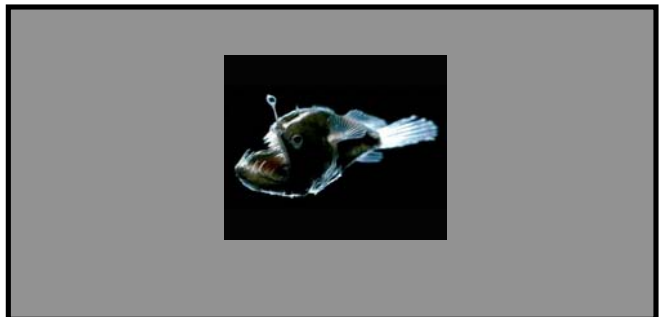
Is the deep ocean a place where we can store extra carbon indefinitely?

- a. yes
- b. no
- c. we don't know
- d. it depends

**b**

## DEEP OCEAN

DEEP OCEAN



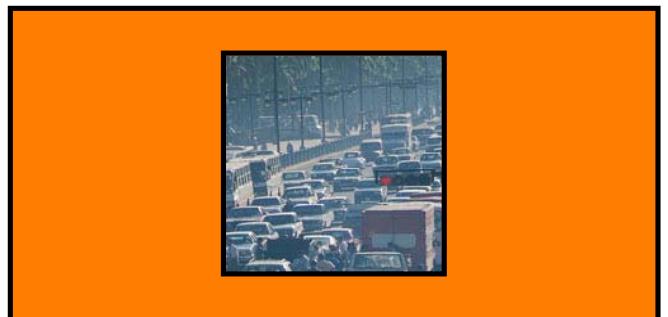
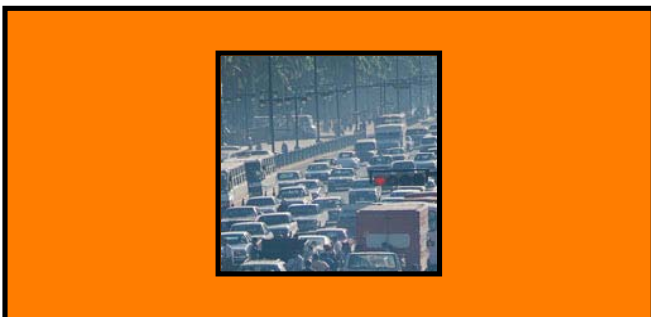
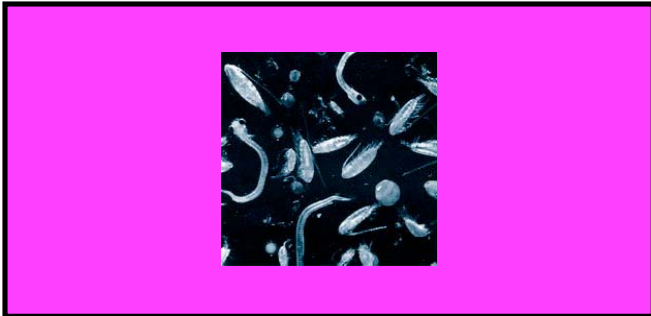
DEEP OCEAN



TEACHER QUESTIONS

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TEACHER QUESTIONS